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GLACIAL DEPOSITS OF THE CONTINENTAL TYPE IN ALASKA[1]

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CONTENTS

[1] Based upon field work by the senior author in 1911, and by the junior author in 1910 and 1911. This paper was written after the lamented death of the senior author on March 21, 1912, and the junior author assumes full responsibility for all

INTRODUCTION

The glaciation of the interior of Alaska forms a striking contrast with that of the coast, where the glacial erosion forms predominate, the deposits being largely under water. The interior, between the coast ranges and the Endicott-Rocky Mountain system, where the National Geographic Society's parties made some studies in 1910 and 1911, has extensive glacial deposits of the continental type, similar to those of United States, and previously described in part by Dawson, McConnell, Russell, Hayes, Spurr, Schrader, Mendenhall, Brooks, and many others. From 1867, when Dall[1] first announced the absence of glaciation on the middle and lower Yukon, to 1906, when Brooks[2] summarized the knowledge of glaciation in Alaska, and continuing to the present time, there has been an increasing amount of specific information concerning the glaciation of the interior of Alaska. Most of this material has been gathered by the geologists of the Alaska Division of the U.S. Geological Survey.

In this paper it is proposed merely to call attention to the availability of this information and to emphasize the conditions in one of the large areas of glacial deposits of the continental type—the Upper Copper River valley—where we made our observations in 1910 and 1911. Here one type of deposit derived from the glacial drift, hitherto not described specifically from Alaska—wind-blown loess or eolian silt—occurs in considerable amount, and is still being deposited.

CONTINENTAL DEPOSITS IN ALASKA

The areas on the coast of Alaska where glacial deposits occur are relatively small—(*a*) 1,600 square miles east of Yakutat Bay, (*b*) 16,000 square miles in the Cook Inlet-Susitna valley region (perhaps to be considered an interior area), and (*c*) smaller areas.

possible errors of interpretation. Professor J. B. Woodworth has been good enough to read and criticize the manuscript.

Read before the Geological Society of America, December 28, 1911.

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[1] *Amer. Journ. Sci.*, Second Series, Vol. XLV (1868), 99.

[2] *Prof. Paper 45*, *U.S. Geol. Survey* (1906), pp. 244–49.

The areas of continental glacial deposits in the interior are much larger and may be computed from Brooks's map (Fig. 1) as follows: at least (*a*) 15,000 square miles in the Copper River basin, (*b*)

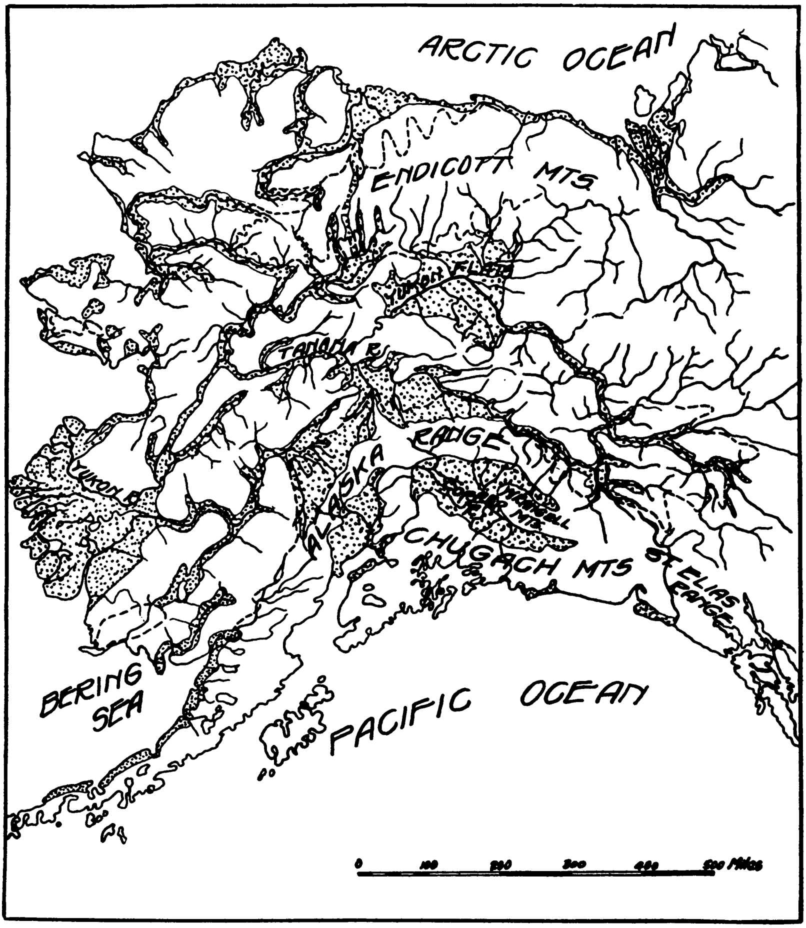

FIG. 1.—Map of Alaska showing areas of glacial deposits of the continental type (dotted areas). Boundaries of glaciation shown by dashed lines. (After A. H. Brooks.)

27,000 square miles in the Tanana and Kuskokwim valleys, (*c*) 17,000 square miles in the Yukon Flats, (*d*) several thousand square miles on the upper Yukon region in Canada, and smaller areas.

The Tanana–Kuskokwim valley area is clearly one of glacial outwash extending far outside the limit of glaciation, as the silt-laden streams from existing glaciers testify. Whether the Yukon Flats area is entirely glacial outwash is not absolutely clear. Russell thought it a flood-plain deposit and Spurr a lake bottom. The narrow strips of Pleistocene silts, sands, and gravels along the rivers, and the broad expanse of the Yukon–Kuskokwim delta have not been specifically considered in this paper, although distant existing glaciers are still supplying much of the sediment even to these regions.

GLACIAL DEPOSITS OF THE COPPER RIVER BASIN

The upper Copper River flows through an intermontane basin which it shares with the headwaters of the Susitna River. This basin is walled in by the Alaska Range and the Nutzotin, Talkeetna, Wrangell, and Chugach mountains. It is clear that the area of Pleistocene in the upper Copper River valley is wholly of glacial origin. The nature of this intermontane basin is such that practically none of the glacial débris escaped down the stream outlets.

Here the topography and the glacial material have been described in more or less detail by Hayes, Schrader, Mendenhall, Spencer, Moffit, Maddren, Capps, and others,[1] and here the junior author of this paper in 1910 and both of us in 1911 made the observations which form the basis of the present discussion.

Area covered by drift.—Throughout over 15,000 square miles (Fig. 1), an area at least equal to the portion of Illinois covered by drift deposits of the last glacial epoch, the basin of the upper Copper and Susitna rivers has glacial deposits which dominate the region.

[1] C. W. Hayes, *Nat. Geog. Mag.*, Vol. IV (1892), 135–36; W. C. Mendenhall, *20th Ann. Rept., U.S. Geol. Survey*, Part VII (1900), 282–84; F. C. Schrader, *ibid.*, pp. 384–86, 410–12; F. C. Schrader, and A. C. Spencer, House Doc. 546, 56th Cong., 2d sess. (1901), pp. 29–30, 58–61, 62–75; Oscar Rohn, *21st Ann. Rept., U.S. Geol. Survey*, Part II (1900), 408–9; W. C. Mendenhall and F. C. Schrader, *Prof. Paper 15, U.S. Geol. Survey* (1903); W. C. Mendenhall, *Prof. Paper 41, U.S. Geol. Survey* (1905), pp. 19–22, 62–74, 79, 88–90; F. H. Moffit and A. G. Maddren, *Bull. 374, U.S. Geol. Survey* (1909), pp. 37–42; S. R. Capps, *Bull. 417, U.S. Geol. Survey* (1910), pp. 36–42; S. R. Capps, *Jour. Geol.*, Vol. XVIII (1910), 38–39; F. H. Moffit and S. R. Capps, *Bull. 448, U.S. Geol. Survey* (1911), pp. 43–52; S. R. Capps, *Jour. Geol.*, Vol. XX (1912), 420–21, 428–30; F. H. Moffit, *Bull. 498, U.S. Geol. Survey* (1912), pp. 30–44, 51–53.

Except near the mountains, no rock outcrops are known. The topography is wholly glacial. The material is till, gravel, sand, silt, clay, and loess.

Thickness of deposits.—The observed thickness of the drift is 500–700 feet[1] in places, and may exceed 1,000 feet. This great thickness, in flat plains at a considerable distance from the mountains, forms a striking contrast with the drift of the region south of the Great Lakes, where it rarely exceeds 400 feet in thickness and averages 115 feet in Illinois, as determined by Leverett, and 40 to 250 feet in southeastern Wisconsin, as determined by Alden.

Plains topography.—The plains topography dominates the upper Copper River valley, the level of the country rising from 600–800 feet, at the southern edge near the lowest outlet of the basin across the Chugach Mountains, to 3,600 feet near the Alaska Range from which the northern portion of the glacial drift was derived, and 5,000 feet on the slopes of the Wrangell Mountains to the east. The broad area of monotonously even plains is shown along the route traversed in 1898 by Mendenhall, from Cook Inlet to the Alaska Range, a distance of over 100 miles, and our own route across this basin in 1911 from the head of the Copper River canyon at Chitina to the Delta Pass, 160 miles.

Streams have cut deeply (500–800 feet) into the outwash plain, opening out wide valleys, either because of recent uplifts, or, as we think much more probable, because of increased ability to erode because the retreating glaciers have retired into the mountains, are no longer excessively overloaded, and have replaced aggradation by degradation. Within the bordering mountain valleys this degradation results in the leaving of lateral terraces of thick bench gravels.

Dominance of outwash.—Outwash gravel, sand, and silt are the chief materials making up the surface of this plain, many of the beds being of alternate weakness and resistance. Lake deposits also make part of the flat topography.

Till of the normal sort.—There is also much till of the normal sort, covering large areas and 400–600 feet thick, but in much

[1] W. C. Mendenhall, *Prof. Paper 41, U.S. Geol. Survey* (1905), p. 63; F. H. Moffit and S. R. Capps, *Bull. 448, U.S. Geol. Survey* (1911), p. 49.

of the Copper River basin the till is buried beneath the outwash. Knobs and kettles, and lakes and swamps are abundant in the till areas. Kames and eskers are present, but thus far no one has found drumlins.

Alternation of beds.—The alternation of silt and gravel with bowlder clay suggests either a complexity of the period of deglaciation, or else that *pro*-glacial outwash gravels, laid down by glacial streams in front of the advancing ice sheet, are to be identified below the till beds, with *post*-glacial outwash, from the retreating ice, above. Sharply folded structures in the stratified clays and silts show the effects of this overriding. Weathering has not been recognized in the lower beds, so that interglacial epochs are not yet suggested by the Alaskan drift.

Volcanic complications.—Near the mountains the presence of lava flows, resting upon, and even intruded in, glacial deposits has been described by Schrader and Spencer,[1] and the complication of past and future ash showers upon the drift is suggested by volcanic ash in some parts of Alaska with thicknesses of a few inches to 75 or 100 feet in an area of many hundred square miles. Present eruptions of Mt. Wrangell, as in April, 1911, show that this process may occur in the future, leaving volcanic ash beds upon or inter-stratified with the till, outwash, and vegetation of the Copper River valley. In at least one locality 35 miles from the nearest active volcano, Mt. Wrangell, enormous masses of angular volcanic rock occur in blocks, buried in the outwash gravels and till beds, suggesting either volcanic showers of large bombs or material carried in glacial floods, as in Iceland. These volcanic fragments are abundantly exposed in 1910 and 1911 in cuts along the newly constructed railway, near Chitina. Other occurrences of the same sort are known, as much as 45 miles from Mt. Wrangell.

Lake deposits.—Large areas of very flat topography with clayey soil suggest former, local, glacial lakes, and some of the sections reveal over 300 feet of fine silt with a few scattered stones, perhaps dropped by floating icebergs. In some sections, measured by

[1] F. C. Schrader and A. C. Spencer, House Doc. 546, 56th Cong., 2d sess. (1901), p. 59 and Pl. XI, A, facing p. 54.

Mendenhall, no striated pebbles were found, but other clays with striated pebbles have been observed.

Sand dunes.—Overlying the outwash and till, in places, are dunes, and the thickness of the sand is over 20 feet in one case. The cross-bedded sand, in other localities beneath till, gravel, and clay suggests either older sand dunes or cross-bedded outwash, but whether in pro-glacial deposits or in recessional deposits of an earlier oscillation is uncertain. The dunes observed are at the very edges of bluffs and the wind-blown material was derived from the modern outwash plains. Dune sand has been described by Schrader and Spencer,[1] and by Mendenhall,[2] and the authors have observed the same phenomena near the junction of the Copper, Chitina, and Kotsina rivers.

Finer wind-blown material than the dune sand has not previously been observed to our knowledge, except by Schrader and Spencer in 1900. They noted[3] that "besides wind-blown deposits in the forms of dunes, the surface soil is frequently composed of fine sand, doubtless of similar origin, and careful investigation would probably show that eolian deposits are rather generally distributed over the Copper Basin."

THE LOESS OR EOLIAN SILT[4] OF THE COPPER RIVER BASIN

Localities.—The localities where we have observed loess soil or eolian silt are (*a*) at Chitina near the southern edge of the Copper River basin just north of the Chugach Mountains; (*b*) at a number of localities along the military trail between Chitina and the Delta River pass across the Alaska Range, scattered throughout a distance of over 160 miles; and (*c*) near the junction of the

[1] F. C. Schrader and A. C. Spencer, House Doc. 546, 56th Cong., 2d sess., 1901, p. 61.

[2] W. C. Mendenhall, *Prof. Paper 41*, *U.S. Geol. Survey* (1905), pp. 64–65, 72.

[3] *Op. cit.*, p. 61.

[4] Professor T. C. Chamberlin has suggested that this coarse wind-blown deposit from Alaska be called by some such name as Eolian silt or Loess soil, because of the desirability of retaining the term Loess as a structural term rather than one that is purely genetic, especially as a hard-and-fast genetic classification could not be justified historically and presents insuperable difficulty in such a region as China, the great home of the loess, where fluvial loess and eolian loess are most intimately intermingled.

Tanana and Delta rivers in the interior plateau. The samples described and the pictures shown are chiefly from the first of these localities, where the loess soil was clearly exposed in 1910 and 1911 in the new railway cuts.

Lithological character.—Most of the eolian silt or loess is dark brown and made up of fine dust. The color is due to included fragments of vegetation, making the deposit resemble the peaty soil which is also abundant in the region.

Professor B. Shimek, of the University of Iowa, who has been good enough to examine our samples, states[1] that they are not

FIG. 2.—Exposure of loess soil or eolian silt near Chitina, Copper River basin, Alaska, with stump horizons.

exactly physically like the loess of United States, one of them resembling the finest sand which sometimes underlies the loess. This coarseness of the material, which is clearly wind-blown, is what should be expected with the different conditions of loess-accumulation in Alaska and in the Mississippi Valley.

The samples collected in Alaska by the authors have been studied under the microscope by Professor Edward Steidtmann, of the University of Wisconsin. They are made up of particles of various minerals, especially mica, a little feldspar, rare quartz, ferro-magnesian minerals, and some carbonates. There is no

[1] Letter, December 23, 1911.

decomposition of the mineral particles, which are exceedingly angular. Their size varies from .03 to .5 millimeters.

As the loess from the Mississippi Valley averages under 0.0025 to .005 millimeters in diameter,[1] and the maximum size rarely exceeds 0.11 millimeters it is apparent that there must be special reasons why these eolian deposits from the Copper River valley in Alaska are exceptionally coarse. The unusual conditions of deposition of this coarse Alaskan accumulations are explained later (p. 300).

Topography.—The topography of this eolian silt is smooth, molded to the underlying bedrock or drift topography, and never dune-like. The exposures show typical steep cliffs, where cut into by streams and by railway grades. There are many vertical joints and the exposure is, therefore, much like those of the loess in the Mississippi Valley and in other localities in the Middle West.

Thickness of deposits.—The thickness is from a few feet to 40 or 50 feet, and in one case 80 feet. Some of the deeper cuts do not reach the bottom of the deposit. In a few places the bottom of the loess soil is revealed as a sharp contact with glacial outwash gravel or till.

Fossils.—Shells of terrestrial[2] animals are abundant in the exposures, and their presence 20 to 40 feet below the surface and back several feet from the faces of cuts in recent railway excavations is clear evidence that these are the fossils of animals which lived during the period of accumulation of the deposits.

Vegetation.—The included vegetation is well-preserved wood in minute fragments and good-sized logs (Fig. 3). There are also upright stumps of trees, up to a foot in diameter and in some of the thicker deposits those are found in layers several feet apart and one above the other. The greatest number of layers of stumps that we have seen was 7, and as these stumps were all clearly in place, it may be assumed that the wind-blown deposit has accumulated during the time necessary for the growth of 7 generations of trees. The present forest upon the loess surface is thick and mature (Fig. 4). Many of the modern trees are 11 to

[1] T. C. Chamberlin and R. D. Salisbury, *6th Ann. Rept., U.S. Geol. Survey* (1885), pp. 279–80.

[2] Collected in 1911 and determined by Professor B. Shimek.

12 inches in diameter. Some of them show 160 rings of annual growth. As there are 7 or more generations of such buried stumps,

FIG. 3.—Five or six generations of stumps buried in loessian deposit near Chitina, Alaska.

this suggests that the region has been deglaciated at least 700 to 1,000 years as a minimum, for during at least this period the eolian deposit has been accumulating.

Relationships of occurrence.—Most of the localities where loess soil has thus far been observed in Alaska are upon the edges of bluffs or within a mile or two of the rivers. Here vast quantities of gravel, sand, and fine silt are being transported by the present glacial streams, which have rather steep grades and flow 5 to 7 miles per hour. The grade of the main Copper River, for example, averages 7 to 12 feet to the mile, in contrast with the Mississippi and Ohio whose grades average less than half a foot to the mile. The mean annual rainfall in the Copper River basin is about

FIG. 4.—Mature forest growing upon wind-blown deposit, Copper River basin, Alaska.

$36\frac{1}{2}$ inches, only 3 or 4 inches of which come during the summer months when the snow is off the ground. The deposits left by the rivers at low water are, therefore, normally dry and easily blown about by the wind. Severe sand and dust storms are prevalent, indicating the origin of these loessian accumulations in Alaska as wind-blown deposits. We ourselves have witnessed these severe dust storms in 1910 and 1911 and they have been reported by many others from Copper River basin and adjacent regions.[1] Rohn states, for example, that on one occasion in 1899 the material whipped up from the outwash plain "was so thick that it was impos-

[1] Oscar Rohn in *W. R. Abercrombie's Copper River Exploring Expedition, 1899*, Washington, Government Printing Office, 1900, p. 127.

sible to see more than a few rods, and to face it was positively out of the question." Upon the loess-covered surfaces there is, variably, (*a*) thick forest (Fig. 4), (*b*) sparse vegetation, (*c*) grassy slopes, and (*d*) bare soil. Near where the present transportation of the finer material by the wind can still be observed, the grass and trees are notably dusty and there are many dead trees, still standing erect. Doubtless the stumps in the loessian deposits represent trees killed by dust accumulating about their trunks. The preservation of this wood seems to be due to burial in the compact eolian deposit, perhaps in part to the frost, which may also have had something to do with the killing of the trees. The shortness of the stumps seems to come from the fact that the wind blew down the dead tree trunk after it was thoroughly dry, but before it was deeply buried in the loess soil.

The conditions found in the Copper River basin favoring the transportation of dust by the wind and the deposition of eolian silt or loess are: (*a*) abundant water from glaciers, (*b*) much sediment, (*c*) anastomosing branches, (*d*) shrinkage of the streams in the fall and spring when winds are strongest, (*e*) a rather dry climate, and (*f*) dust storms.

In comparison with other areas of similar accumulations the Copper River basin has loessian accumulations as (*a*) terrestrial deposits; (*b*) as in some cases (for example, the Mississippi Valley) associated with glaciation; (*c*) as in some, perhaps all, cases, thickest along rivers; (*d*) coarser than that of the Mississippi Valley. This coarseness may be due to (1) the nearness of the rivers; (2) the violence of the winds here; (3) the coarser sediment carried in the steep-grade streams of Copper River basin as compared with the less steep grade of the Mississippi and its glacial tributaries.

CONCLUSION

The presence or absence of all these drift deposits seems to be chiefly a matter of favorable topography and drainage. The deposition of the loess or eolian silt seems to be directly related to the glacial outwash, to variations of river volume and water level, to the amount of rainfall, and to the winds. Existing deglaciation in the interior of Alaska is apparently a process much like that formerly in progress in northeastern and central United States.